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Extreme Precipitation Trends Over the Middle of Indochina Peninsula during the Period from 1978-2007

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Abstract: *The present study focuses on extreme precipitation trends over the middle of Indochina Peninsula for 30 years from 1978-2007. We use daily gridded precipitation data obtained at 0.5° horizontal grid resolution from APHRODITE (Asian Precipitation-Highly Resolved Observational Data Integration Towards Evaluation of Water Resources) to detect the trends with the use of the Man-Kendall and Theil-Sen approach. Extreme precipitation indices were selected from the WMO–CCL/CLIVAR list with a set of twelve indices of precipitation extremes by focusing on precipitation intensity and frequency. It was found that eight out of twelve indices were shown to be statistically increasing trends. The rate of change in the significant trend is greater than 20% for both the increasing and decreasing trends. In addition, spatial distributions of the significant extreme indices over the basins are also discussed in terms of extremely increasing and decreasing trends. The Wang and Northern Mekong, Mae Klong and Phetchaburi indicate increasing the trend of indices while the decreasing trends of indices were found over the Chi and Mun basins.*

Keywords: *Precipitation Trend, Extreme Precipitation, Indochina Peninsula, River basins*

1. Introduction

The increasing of trace gas such as carbon dioxide over the 20th Century has rapidly intensified global climate change. Global and regional land surface air temperatures obtained from station observations are in broad agreement that land surface air temperatures have increased. Globally averaged combined land and ocean temperature data indicated that the surface temperature has increased about 0.72 °C between the years 1951–2012 [6]. The alternations in precipitation amount and storm patterns based on this process could lead to variability in some regions. Observed precipitation change over land from 1901 to 2010 has indicated a more gradual change compared to temperatures [6]. However, the precipitation change varies in spatial and temporal dimensions. Thus, regional variations of precipitation change are of considerable concern and need to be investigated. In this study, the middle of Indochina Peninsula (ICP) is studied to determine extreme precipitation trends.

An observed annual maximum 1-day precipitation (RX1day) over global land areas with sufficient data samples indicates a significant increase in extreme precipitation globally, with a median increase of about 7% °C^{-1} of the global mean surface temperature increase [17]. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) anticipated that the threats are arguably the increasingly frequent and more intense extreme climate events such as tropical cyclones, floods and droughts. They have also addressed the need to assess climatic change at sub-national and local scales [5]. Consequently, the detection of precipitation trends in the historical climate at the basin scale is useful for national planning to assess the impact of these changes.

There are several methods that were used to assess the trends in a hydro-meteorological time series. Recently, various parametric and non-parametric statistical tests were used by many researchers in several countries and regions of the world (e.g., [7, 20, 19]). It has been recognized that there are an increasing number of studies focusing on precipitation trends over the ICP (e.g., [2, 9, 14]). Endo et al. [2] investigated trends in precipitation extremes using high-density station data from Southeast Asian countries from the 1950s to the early 2000s. They found that the number of stations with a significant upward trend is larger than that with a significant downward trend. To our knowledge, we have found that there has been no research to quantify spatiotemporal extreme precipitation trends over the middle of ICP at river basins. Thus, the present study intends to investigate spatial and temporal extreme precipitation trends over the basins in the middle of ICP.

2. Study area

The study area is located in the middle of ICP which is major part of Thailand, as shown in Figure 1. The lower part of Thailand is excluded from the analysis because it has a different precipitation system affecting those areas [15]. There are nineteen basins within the area (shown in Table 1) where it spans over

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a domain size of 11°30′ to 20°30′N latitude and 97°30′ to 105°30′ E longitude. The central flood plain is the main source of agriculture activity where the Chaophraya basin is located, as shown in Figure 1. The northern area of the present study is mountainous, while the northeast area has a higher elevation called Korat Plateau, which inclines from west to east and forces the river to flow eastward toward the Mekong River.

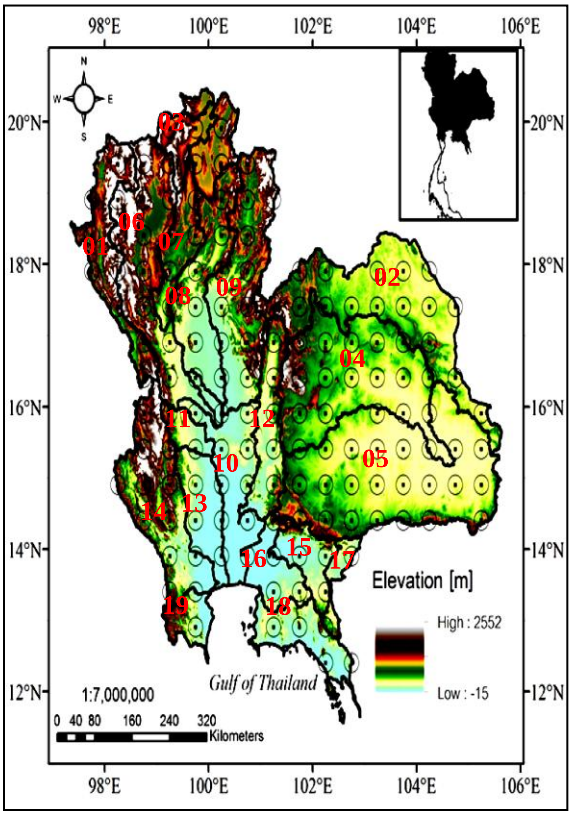

Figure 1. *Topography of study area covering the middle of Indochina Peninsula. Black boundary indicates extent of basins. Points indicate center point of gridded precipitation data. Numbers correspond to basin names referred to in Table 1*

The climatological annual mean precipitation over the study area is 1,332 mm, which was averaged from 1978-2007, as shown in Figure 2a. The climatological mean precipitation varies over the study area. The climatological mean precipitation near the Gulf of Thailand is at 12°12'N latitude and 102°35' E longitude is 2,300 mm, while the Chaopraya River basin is at 15°N latitude and 100°E longitude and receives a relatively low amount of precipitation at 790 mm.

In addition, the northern area (18°N latitude and 100°E longitude) has a lower climatological mean precipitation of 1,010 mm. The northeast area over the Chi basin has a lower climatological precipitation rate of around 900 mm. The spatial distribution of precipitation there indicates an increasing amount toward Mekong River. Precipitation over the study area shows increasing trends at a rate of +2.62 mm year-1 from 1978-2007 as shown in Figure 2b. There are fluctuations of precipitation in particular years.

Table 1*. River basin names and their area size located in the present study*

Code	Basin Name	Area (Sq.Km)
01	Salawin	19,179
02	Mekong	57,144
03	Kok	7,321
04	Chi	49,140
05	Mun	70,944
06	Ping	34,688
07	Wang	10,837
08	Yom	24,142
09	Nan	34,803
10	Chao Phraya	20,604
11	Sakae Krang	4,928
12	Pasak	15,678
13	Tha Chin	13,536
14	Mae Klong	30,313
15	Prachinburi	9,674
16	Bangprakong	10,742
17	Tonle Sap	4,098
18	East Coast Gulf	13,531
19	Phetchaburi	6,280

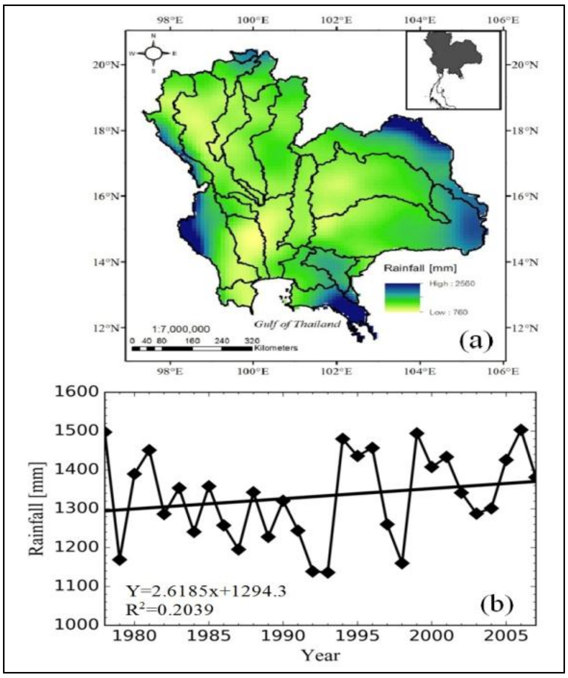

Figure 2. *Climatological mean precipitation over the middle of ICP from 1978-2007 including (a) map of climatological precipitation, and (b) area average of climatological mean precipitation; regression line is represented as a trend of precipitation*

3. Methodology

3.1. Data

To identify extreme precipitation trends over the study area, daily gridded precipitation data is obtained at 0.5° horizontal grid resolution from APHRODITE (Asian Precipitation-Highly Resolved Observational Data Integration towards Evaluation of Water Resources) [18]. The gridded precipitation data has been widely used in several application research studies related to hydro-climatological fields (e.g., [1]). Daily and computed annual precipitation data from the daily gridded precipitation dataset a period of 30 years (1978-2007) were used to discover a trend of extreme precipitation indices. The total number of grids is 151 points that cover the inland area of the present study region. Extreme precipitation indices were adapted from the WMO–CCL/CLIVAR list [11]. We selected a set of twelve indices of precipitation extremes following Endo et al. [2], as shown in Table 2. Indices numbered 1-6 indicate the precipitation intensity, while indices numbered 7-12 indicate the precipitation frequency. A wet day refers to day that has precipitation of at least 1 mm, while a dry day has precipitation of less than 1 mm.

***Table 2**. Precipitation indices and their definitions and units. RR is the daily precipitation rate. All indices are calculated annually from January to December*

No	*Index*	*Definitions*	*Units*
1	PRCTOT	Annual total precipitation from wet days	mm
2	SDII	Average precipitation from wet days	mm day^{-1}
3 4	R95p R99p	Precipitation amount per year above threshold value for very and extremely wet days, calculated as the 95th and 99th percentile of the distribution of daily precipitation amounts on days with 1 mm	mm
5	RX1day	Annual maximum 1-day precipitation	mm
6	RX5day	Annual maximum consecutive 5-day precipitation	mm
7	WDAY	Number of days with daily precipitation≥1 mm	days
8 9 10	R10mm R20mm R50mm	Number of days per year with precipitation amount ≥10 mm, ≥20 mm, and > 50 mm, respectively.	days
11	CWD	Annual maximum number of consecutive wet days	days
12	CDD	Annual maximum number of consecutive dry days	days

3.2 Mann-Kendall test

In this study, the Mann-Kendall (MK) test [8, 10] was used to detect the statistical significance of a trend of gridded precipitation data. The MK test is a non-parametric test that searches for a trend in a time series without specifying whether the trend is linear or non-linear. It has been used in many research applications to assess the significance of trends in hydroclimate time series data such as water quality, stream flow, temperature, and precipitation (e.g., [2, 20]). In this study, the statistical significance level (α) was set to be 0.10 and 0.05. The magnitude of a trend (β) is estimated using an approach proposed by Theil [16] and Sen [13], which hereinafter is referred to as TSA (e.g., [4, 21, 12]). The slope of the trend was estimated from the median of TSA of the slope (β). The true slope was obtained by a non-parametric test which was tested by a two-side at 100 (1-α) % confidence interval. The details of the calculation were referred to by Pingale [12]. The magnitude of the trends of the gridded precipitation data is calculated as the percentage of increase or decrease of the mean (E (X^k)) of the sample data over the observation period (T) as grid k can be given by

$$B_k = 100 \times \frac{T\beta}{E(X^k)} (\%)$$

4. Results and Discussion

4.1 Trend of extreme precipitation in the middle of ICP

Figure 3 summarizes the percentage of grids with statistically significant trends in precipitation indices over the middle of ICP. The number of grids with statistically significant trends is generally less than about 25%, except for the increasing trends in WDAY which are shown as exceeding 35% of the number of grids. WDAY has statistical significance of the increasing trends which are those grids that are widely distributed over the region as shown in Figure 4b. In addition, CWD is the second highest statistical significance of the increasing trends at 23% of the total number of grids. Significant increasing trends of CWD grid are located in Wang, Yom and Nan basins in the northern Thailand, while Mun, Chi and Mekong basins indicate significant increasing trends in northeastern Thailand, as shown in Figure 5e.

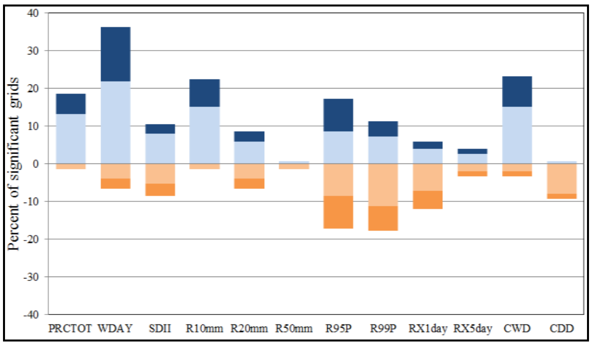

***Figure 3.** Percentage of grids with statistically significant trends in precipitation indices over the middle of ICP. Dark blue (dark orange) and light blue (light orange) indicate increasing (decreasing) trends at significance level of 5% and 10%, respectively*

An extremely wet day is higher than the significant decreasing trends indicated in R99P, R95P and RX1day indices. The Mun and Chi basins are located in the zone of statistically significant decreasing trends of R95P and are much coinciding with R99P which accounted for 17% and 18% of the total number of grids, respectively. The statistically significant decreasing trend of RX1day was widely distributed with stronger precipitation intensity over the Chi basin, as shown in Figure 5c.

PRCTOT had the most significant increasing trends distributed over two regions concentrated in northern Thailand and near the Gulf of Thailand, including Bangkok, as shown in Figure 4a. Significant increasing trends for PRCTOT were found over major tributaries of the Chao Phraya basin, which include the Wang, Yom, Nan basins, all of which had a percentage of change in precipitation greater than 20% over the observed period. Endo et al. [2] found that statistically significant decreasing trends were observed at six locations around Bangkok, meaning that the present results differ from theirs. It was found that there were significant grids of decreasing trends around Bangkok. The difference is mainly due to different data in the lengths and periods examined. However, the statistically significant decreasing trends on their results over northeastern Thailand are in agreement with the present study. Furthermore, Limjirakan et al. [9] indicated that precipitation in the Bangkok metropolitan area had statistically significant increasing trends from 1965-2006 which is consistent with the present study.

WDAY had a widely spatial distribution of significant increasing trends over the study area but a rather small percentage of changes in precipitation, as shown in Figure 4b. The northeastern region showed statistically significant increasing trends over the Mun, Chi and Mekong basins. In addition, the east coast gulf basin had a majority of the grids with significant increasing trends at the 5% significance level as the percentage of changes in precipitation in the class of 10-20% over the observation period. The Mae Klong basin had a percentage change in the significant increasing trends at greater than 20% which was distributed in the mid-section of the basin. In addition, the lower part of the Nan basin had statistically significant decreasing trends with a rather small percentage of changes in precipitation at less than 10%.

SDII had statistically significant increasing trends in the west of the study area, while the statistically significant decreasing trends were located in the eastern region, as shown in Figure 4c. The Phetchaburi basin had statistically significant increasing trends with percentage changes of greater than 20%. In addition, The Chi basin had statistically significant decreasing trends with percentage changes of greater than 20%. The present study has a spatial pattern of SDII that is consistent with Endo et al. [2].
R10mm had statistically significant increasing trends over the Wang, Yom, Nan and east coast gulf basins in widely spatial distribution, as shown in Figure 4d. The percentages of changes in significant trends were mostly greater than 20%. R20mm had statistically significant increasing trends in the Phetchaburi basin, while statistically significant decreasing trends were located over the Chi basin, as shown in Figure 4e. The spatial distribution of R10mm in northern Thailand has an overlapping area with some significant grids of PRCTOT, SDII, R95P, and CWD. Therefore, stronger precipitation intensity may occur on consecutive days, although WDAY is not consistent with those mentioned indices. Sharma and Barbel [14] found that rainfall greater than 10 and 20mm (R10mm and R20mm) had declined insignificantly at all stations over the Ping and Mae Klong basins. Compared to the present results, we found that R20mm is quite consistent with the previous study because the significant trends were found.

R95P had similar spatial distribution for both the increasing and decreasing trends as shown in Figure 5a. The significant increasing trends were located in the west and significant decreasing trends were located in the eastern part of the region. R95P had significant increasing trends in the Wang and Yom basins in northern Thailand, while the most significant increasing grids were over the Phetchaburi basin with a percentage of change greater than 20% at the 5% significance level. In addition, significant decreasing trends in R95P were located in the Mun and Chi basins, as shown in Figure 5a. R99P showed that most of the significant increasing grids at the 5% significance level were over the Phetchaburi and Mae Klong basins, while significant decreasing grids were widely distributed over the Chi basin with the percentage of change greater than 30%, as shown in Figure 5b.

RX1day had significant increasing trends over the Phetchaburi basin in a widely spatial distribution with a percentage of change greater than 20%, as shown in Figure 5c. In addition, most of the grids with a percentage of change greater than 20% of RX1day were widely distribution over the Chi basin. The spatial distribution of RX1day is similar to R95P and R99P in terms of significant decreasing trends. Generally, RX5day has a spatial distribution of significant trends similar to RX1day, R95P and R99P in the northern part of the study area as shown in Figure 5d. RX5day had significant increasing trends over the Wang basin, while significant decreasing trends were located over the Chi basin.

CWD had significant increasing trends which were widely distributed over the region compared to the other indices as shown in Figure 5e. The Wang, Yom and Nan basins had significant increasing trends located in the upper stream. Significant increasing trends in northeastern Thailand were found over the Mun, Chi and Mekong basins implying that the area may have a larger amount of rain with strong precipitation intensity when considered among other intensity indices contained therein. In addition, significant decreasing trends are located in the Mun basin. CDD had significant decreasing trends in the western part of the study area located in the Ping, Wang, Yom, Mae Klong and east coast gulf basins as isolated grids, as shown in Figure 5f. The spatial pattern of significant decreasing trends in CDD is consistent with the CWD pattern. Therefore, it could imply that in the west of Thailand and near the coast may have consecutive days of extreme precipitation lasting longer with significant increasing trends.

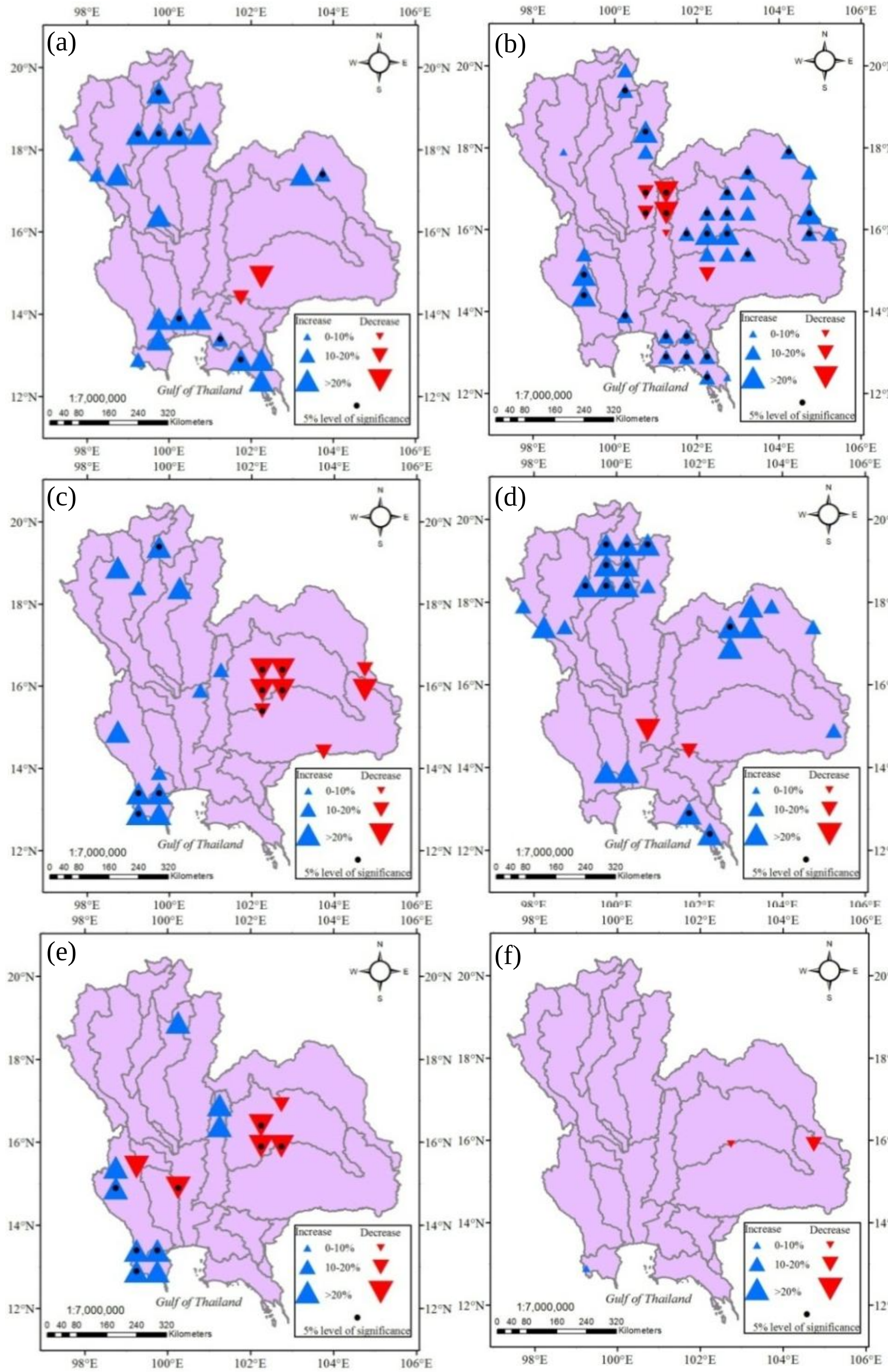

Figure 4. *Trends in (a) PRCPTOT, (b) WDAY, (c) SDII, (d) R10mm, (e) R20mm, and (f) R50mm. Trends are expressed as percentage variations with respect to the mean value using Sen's estimator of slope from 1978-2007. Blue (inverse red) triangle indicates increasing (decreasing) trends at 90% confidence level. Circle solid symbol denotes 95% confidence level of trends*

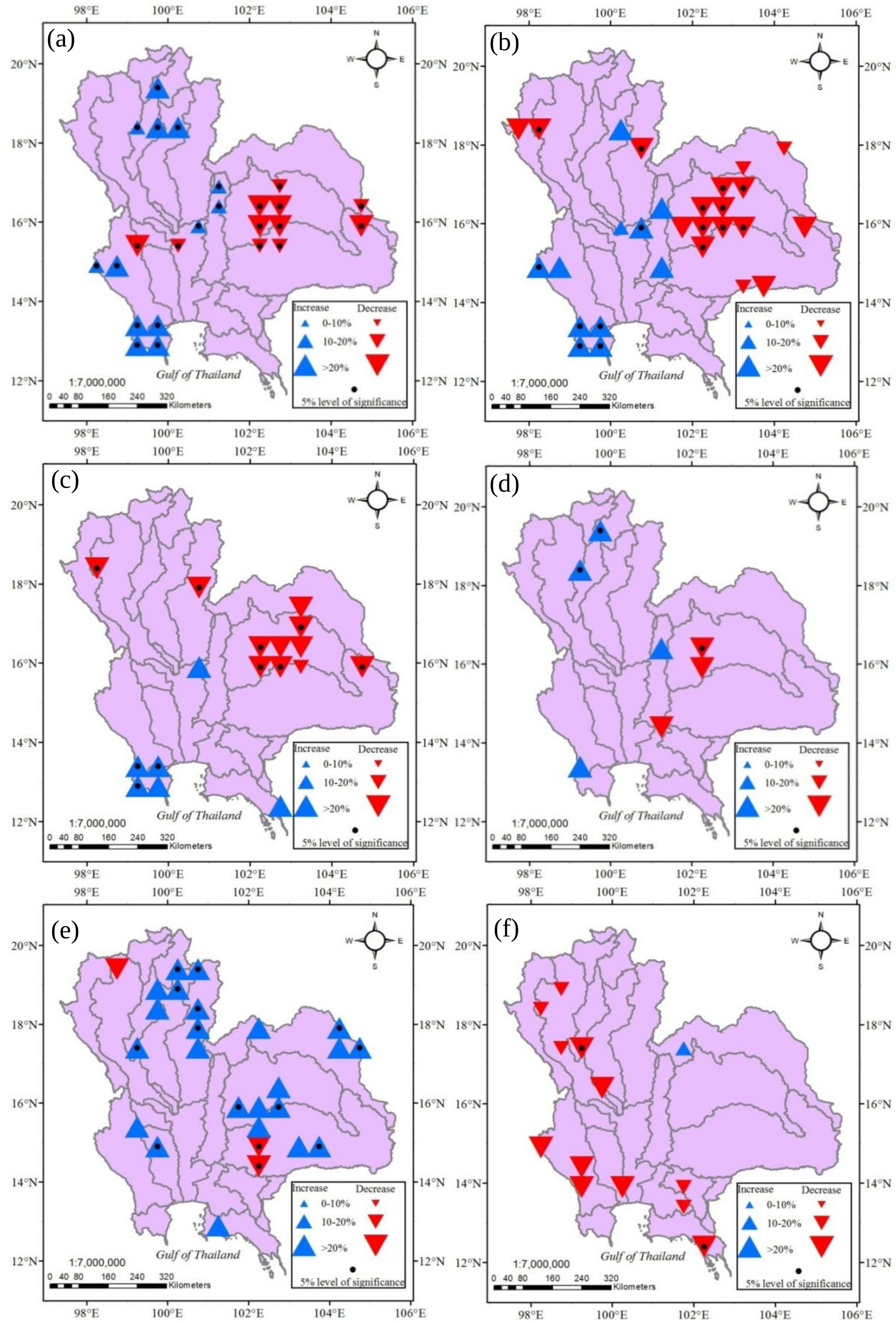

Figure 5. *Same as Figure 4, except for trends in (a) R95P, (b) R99P, (c) RX1day, (d) RX5day, (e) CWD and (f) CDD*

4.2 Frequency precipitation indices

The frequency map of extreme indices at a 95% confidence level was produced on a basin basis in order to discuss the spatial variations, as shown in Figure 6.

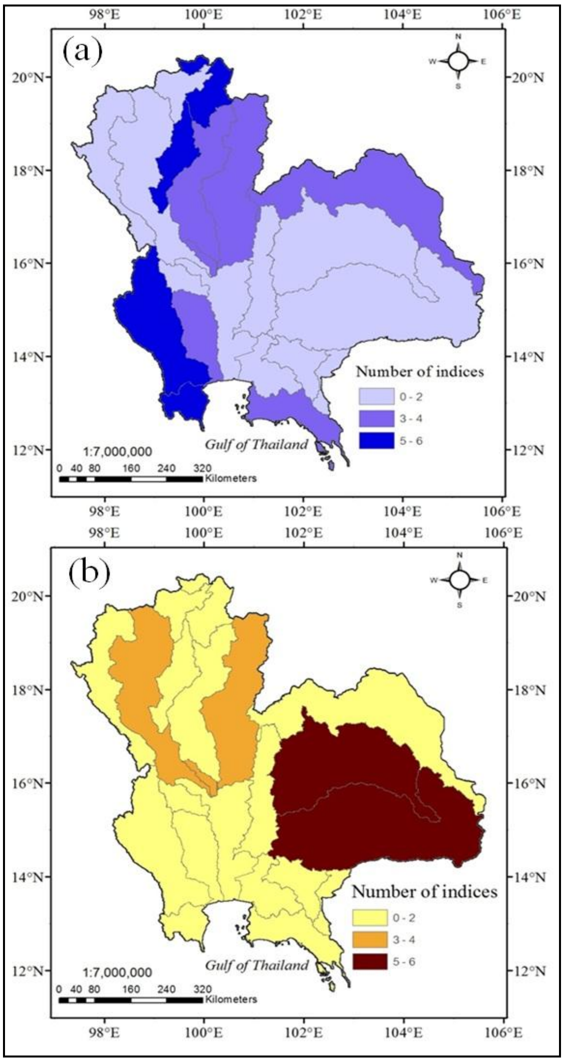

Figure 6. *Map of frequency precipitation indices of 95% confidence level. (a) Increasing trends (b) decreasing trends*

Figure 6a shows two contiguous areas of the basin that contain the highest frequency of extreme indices in the statistically significant increasing trends in the frequency class of 5 to 6 indices per basin. The first area consists of the Wang and Northern Mekong basins, while the latter area consists of the Mae Klong and Phetchaburi basins. River tributaries, which are the Wang, Yom, and Nan basins of the Chao Phraya basin have a high frequency of extreme indices, except for Ping basin. These basins are important to the Chao Phraya basin because they serve as the main water input to the basin. Increasing precipitation in these basins may affect the water budget of the Chao Phraya basin, although the Chao Phraya basin does not have a high number of extreme precipitation indices. It was found that the Wang and Northern Mae Klong basins have a rate of percentage of changes for R95P at +3.33 mm year-1 as shown in Figure 7a, while the Mae Klong and Phetchaburi basins have a rate of percentage of change for R99P at +1.72 mm year^{-1} during the study period, as shown in Figure 7b.

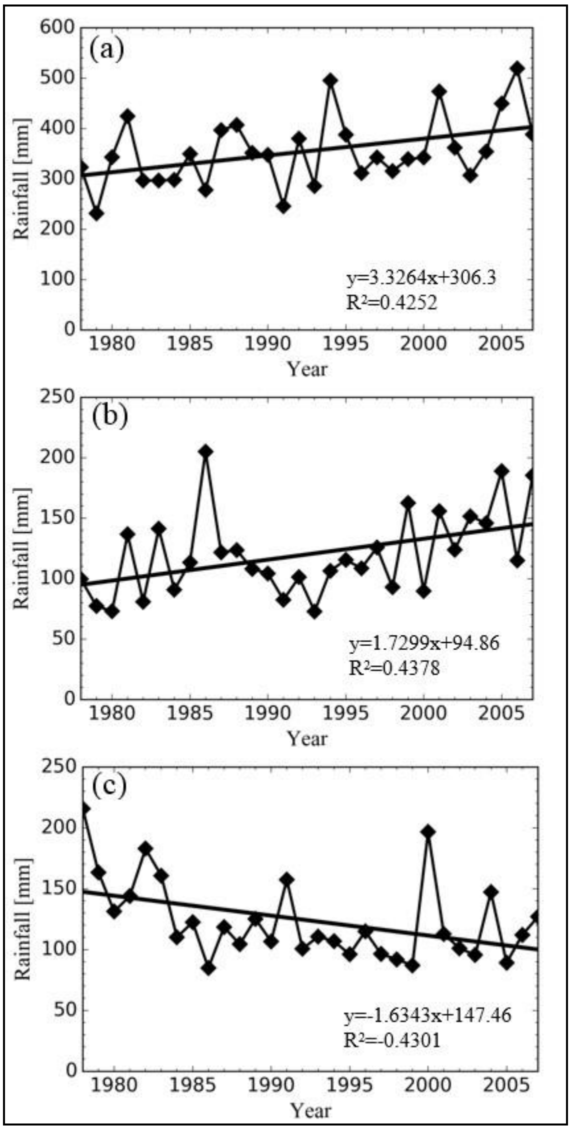

Figure 7. *Time series percentage of changes of indices from 1978 to 2007 over the highest number of indices contained in the contiguous areas of basins (a) R95P of Wang and Northern Mekong basins, (b) R99P of Mae Klong and Phetchaburi basins , and (c) R99P of Chi and Mun basins*

Fudeyasu et al. [3] investigated the impact of ENSO on the landfall characteristics of tropical cyclones (TC) over the WNP during the summer monsoon season. During the peak monsoon period (late July–mid September), the number of TCs that made landfall in the ICP was greater in the El Niño years than in the La Niña years. Therefore, extreme precipitation may occur over these two contiguous basins from an impact of tropical landfall on R95P and R99P.

The Chi and Mun basins have the highest frequency of extreme indices in statistically significant decreasing trends, as shown in Figure 6b. The Chi and Mun basins have a rate of percentage of change for R99P at -1.63 mm year^{-1} as shown in Figure 7c. These two basins are very important to those who live in the northeastern Thailand, where the largest amount of the Thailand's population resides. This may affect to their livelihoods which rely primarily on agriculture. The government should find a measure to support a sustainable crop for farmers to cope with extremely dry or wet conditions.

5. Conclusions

Extreme precipitation trends were investigated over the middle of Indochina Peninsula (ICP). The APHRODITE gridded precipitation data was employed in the number of 151 grids for a period of 30 years from 1978-2007. Extreme precipitation indices were selected from those that were adapted from the WMO list and include twelve indices to quantify both intensity and frequency. Each of the grids was computed in a time series to find the significant trend of extreme indices with the use of Man-Kendall (MK) and computed the median slope of the trend with the approach of Theil [16] and Sen [13]. The concluded results of the present study are summarized as follows:

a. The number of the significant increasing trends of gridded data is relatively larger than the significant decreasing trends. There are eight out of twelve indices that indicate statistically significant increasing trends over decreasing trends.

b. The rate of percentage of change in significant trends is classified into three classes, which are less than 10%, 10-20% and greater than 20%. It was found that the rate of the percentage of change in both increasing and decreasing trends was mostly in the class of greater than 20% during the observed period, except for WDAY.

c. Spatial distribution of the significant extreme indices is located in the contiguous basins of three groups. The first and the second basin groups contained the highest number of increasing indices which are the Wang and Northern Mekong, Mae Klong and Phetchaburi basins. The last basin group indicates the decreasing indices that are the Chi and Mun basins.

Further investigation of the extreme precipitation trends is carried on toward understanding the seasonally spatial pattern of the extreme precipitation.

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References

[1] Awan, J. A., Bae, D-H., Kim, K-J., "Identification and trend analysis of homogeneous rainfall zones over the East Asia monsoon region", International Journal of Climatology, 35, PP. 1422–1433, 2015.

[2] Endo, N., Matsumoto, J., Lwin, T., "Trends in precipitation extremes over Southeast Asia", SOLA, 5, PP. 168–171, 2009.

[3] Fudeyasu, H., Iizuka, S., Matsuura, T., "Impact of ENSO on landfall characteristics of tropical cyclones over the western North Pacific during the summer monsoon season", Journal of Geophysical Research, 33, 2006.

[4] Hirsch, R. M., Slack, J. R., Smith, R. A., "Techniques of Trend Analysis for Monthly Water Quality Data", Water Resources Research, 18(1), PP. 107–121, 1982.

[5] IPCC, "Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]", Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007.

[6] IPCC, "Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]", Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2013.

[7] Karl, T. R., Knight, R. W., "Secular Trends of Precipitation Amount, Frequency, and Intensity in the United States", Bulletin of the American Meteorological Society, 79(2), PP. 231–241, 1998.

[8] Kendall M. G., "Rank Correlation Methods", Griffin, London, England, 1975.

[9] Limjirakan, S., Limsakul, A., Thavivongse, S., "Trends in temperature and rainfall extreme changes in Bangkok metropolitan area", Environmental Research, 32(1), PP. 31–48, 2010.

[10] Mann, H. B., "Nonparametric Tests Against Trend", Econometrica, 13, PP. 245–259, 1945.

[11] Peterson, T. C., Folland, C., Gruza, G., Hogg, W., Mokssit, A., Plummer, N., "Report on the activities of the Working Group on Climate Change Detection and Related Rapporteurs 1998–2001", World Meteorological Organisation Rep. WCDMP-47, WMO-TD 1071, Geneva, Switzerland, 2001.

[12] Pingale, S. M., Khare, D., Jat, M. K., Adamowski, J., "Spatial and temporal trends of mean and extreme rainfall and temperature for the 33 urban centers of the arid and semi-arid state of Rajasthan, India", Atmospheric Research, 138, PP. 73–90, 2014.

[13] Sen, P. K., "Estimates of the Regression Coefficient Based on Kendall's Tau", Journal of the American Statistical Association, 63, PP. 1379–1389, 1968.
[14] Sharma D., Babel, M. S., "Trends in extreme rainfall and temperature indices in the western Thailand", International Journal of Climatology, 34, PP. 2393–2407, 2014.
[15] Tangang, F. T., Juneng, L., Salimum, E., Vinayachandran, P. N., Kok Seng, Y., Reason, C. J. C., Behera, S. K., and Yasunari, T., "On the roles of the northeast cold surge, the Borneo vortex, the Madden-Julian Oscillation, and the Indian Ocean Dipole during the extreme 2006/2007 flood in southern Peninsular Malaysia" , Geophysical Research Letter, 35.
[16] Theil, H., "A Rank-Invariant Method of Linear and Polynomial Regression Analysis, I, II, III", Nederl. Akad. Wetensch. Proc, 53, PP. 1397–1412, 1950.
[17] Westra, S. L., Alexander, V., Zwiers, F. W., "Global increasing trends in annual maximum daily precipitation", Journal of Climate, 26, PP. 3904–3918, 2013.
[18] Yatagai A., Kamiguchi, K., Arakawa, O., Hamada, A., Yasutomi, N., Kitoh, A., "AHPRODITE: constructing a long-term daily gridded precipitation dataset for Asia based on a Dense Network of Rain Gauges", Bulletin of the American Meteorological Society, 93, PP. 1401–1415, 2012.
[19] Yavuz, H., Erdogan, S., "Spatial analysis of monthly and annual precipitation trends in Turkey", Water Resources Management, 26 (3), PP. 609–621, 2012.
[20] Yue, S., Hashino, M., "Long term trends of annual and monthly precipitation in Japan", Journal of the American Water Resources Association, 39(3), PP. 587–596, 2003.
[21] Zhang, X., Vincent, L. A., Hogg, W. D., Niitsoo, A., "Temperature and Precipitation Trends in Canada During the 20th Century", Atmosphere Ocean, 38(1), PP. 395–429, 2000.